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COMBUSTION AND UTILIZATION EFFICIENCIES OF RESIDENTIAL FURNACES AND WATER HEATERS STATE-OF-THE-ART

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Efficiencies for oil and gas-fired furnaces and gas water heaters are examined and losses identified. Retrofit items and redesigned appliances are described, and their effects on efficiency summarized. Of the three appliance areas studied, gas furnaces have taken the lead in increased efficiency, while oil furnaces are in the process of being improved. Little attention has been paid to improving gas water heaters.

1.0 INTRODUCTION

In North America, the rising price of fossil fuels has provided the incentive for consumers to purchase high efficiency, higher priced space and water heating appliances. In response to the new demand and with the aid of Government support, the R&D facilities of the oil, gas and appliance industries have developed significantly improved gas furnaces and moderately improved oil furnaces and water heaters. For example, the conventional gas furnace of the pre-OPEC era possesses a typical seasonal efficiency of 55 to 65%/1/. The pulse combustion furnace introduced in 1983 is about 95% efficient seasonally/2/. This report attempts to document the innovations made to these space and water heating appliances during the last decade.

The improvements have resulted from two trends in the quest for higher efficiencies; first, the development of retrofit items for existing appliances and second, the redesign and development of new appliances. Both trends are examined under each of the three appliance areas studied: gas furnaces, oil furnaces and gas water heaters.

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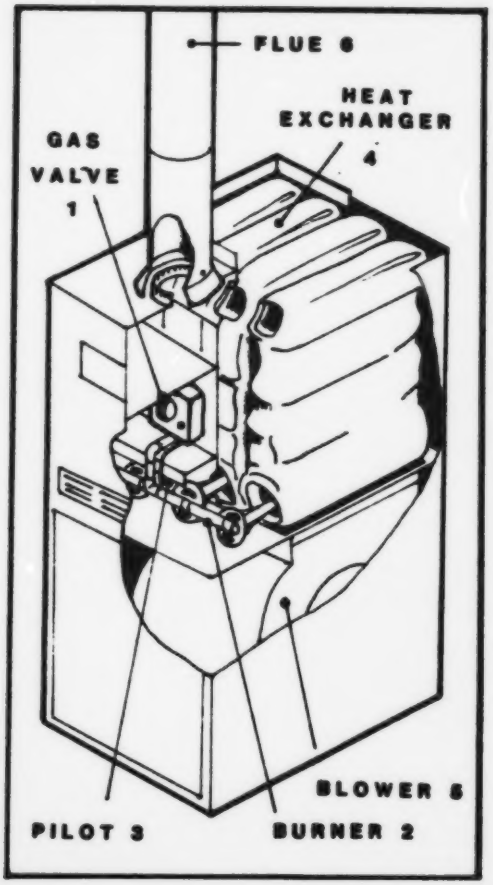
2.0 GAS FURNACES

Residential gas-fired space heating furnaces are discussed first as they have received the most R&D attention during the last 10 years. As was mentioned earlier, the conventional gas furnace is between 55 and 65% efficient seasonally. A brief discussion of furnace operation will highlight the reasons for this poor performance.

Figure 1 is a cutaway view showing the burner arrangement and "clamshell" heat exchanger found in more than 90% of the conventional gas furnaces in use today/3/. It operates as follows: when the gas valve assembly (1) receives a demand for

Figure 1

Conventional Gas Furnace



heat from the thermostat, it opens sending gas into the burners (2) Combustion air aspirates into the burners, mixes with the gas and is ignited by the pilot flame (3) the heat of combustion passes through the heat exchanger walls (4) warming the air delivered by the blower (5) into the ductwork of the residence. The hot combustion products are drawn out of the heat exchanger and into the flue (6) by their own buoyancy. When heating demand is satisfied, the gas is shut off by the valve and the blower stops after the furnace has cooled down/4/.

There are two categories of heat loss associated with the operating cycle described; on-cycle losses which are a result of combustion and heat transfer inefficiency, and off-cycle losses resulting from stack-effect and standing pilot losses. These are further explained below.

ON-CYCLE LOSSES

Governing standards require that the heat exchanger in a gas furnace be at least 75% efficient/5/,/9/. This means that at steady state, three-quarters of the heat released by combustion must be transferred to the air delivery system of the house. The remaining heat is contained in the flue gas. The reason for letting so much heat escape is two-fold. Flue gas is exhausted by its own buoyancy, therefore it must be hotter than ambient air. A large portion of flue gas heat is stored as latent heat in water vapour, so exhausting cooled flue gas would mean risking condensation in the chimney, or worse, in the steel heat exchanger where it could cause corrosion.

It is estimated that of all the heat generated by combustion, approximately 10% is latent heat stored in water vapour/6/. The remainder of the lost heat is found in hot flue gas. Aside from combustion and heat transfer inefficiency, on-cycle losses are increased by furnace location. If it is outside the heated space, jacket losses reduce efficiency by 1-2%[1]/3/. If it is inside, the same amount is lost because the furnace draws combustion air from the heated space. Even more air is aspirated into the flue to dilute the flue gasses. All this heated air is replaced by cold air seeping into the residence, further reducing the effectiveness of the furnace. An improper gas/air mixture at the burners can reduce efficiency by another 3 to 4%/1/. Thus, while the rated combustion efficiency for a given gas furnace may be anywhere between 75 and 80%, the actual on-cycle efficiency is lower.

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[1] In this report, losses or efficiency improvements are expressed as percentage points (ie a 5% improvement in efficiency of a 75% efficient furnace would result in that furnace operating at an efficiency of 80%).

OFF-CYCLE LOSSES

During the furnace off-cycle, losses occur mainly due to stack effect. Because most gas furnaces are located in the heated space, they continually draw heated air from the room into the flue. This action is aided by the standing pilot which burns at a low rate and causes buoyant combustion products to aspirate air from the room into the flue. Losses due to the pilot burning during the non-heating season are estimated to be 1 or 2%/3/. Much greater are the stack losses which reduce efficiency by anywhere from 13 to 19%/3/.

TOTAL LOSSES

Furnaces have traditionally been sized to match the heat load of a house on the coldest (design) day of the winter. This means that a furnace will generally be oversized to meet the average heating demands of a house. The resulting effect can be imagined. While the heating load varies gradually throughout the day, the furnace can only match the heat demand with short high energy bursts of heat. This operation, combined with the on-and off-cycle losses, tends to reduce the efficiency of the conventional gas furnace system/7/ to the typical seasonal value of 55 to 65%.

RETROFIT DEVICES FOR HIGHER EFFICIENCY

One trend towards improving the efficiency of existing conventional gas furnaces has been the development of devices that would reduce or eliminate some of the cyclic losses discussed previously. An electronic ignition can replace the standing pilot for example. Flue dampers can isolate the flue during the off-cycle period, reducing the stack losses and thereby increasing the seasonal efficiency. Heat reclaimers mounted in the flue can remove some of the heat from the flue gas and return it to the warm air delivery system.

In North America, the majority of these devices have been developed and approved for retrofit in the United States. Canadian authorities have been reluctant to approve, for retrofit, many of the devices which affect flue gas flow and temperature out of a concern for safety. Instead, devices such as flue dampers are available as integrated components in the first generation high efficiency furnaces now being promoted by the gas appliance manufacturers.

Nevertheless much research has gone into the testing and documenting of these device efficiencies on both sides of the border. The results where documented have been summarized in Table 1. A detailed description of the devices listed can be found in Appendix 1.

TABLE 1

RETROFIT DEVICE EFFICIENCIES FOR GAS FURNACES

Device	Cycle		Efficiency		Installation	
	On	Off	Claimed	Tested	Retrofit	New
Automatic Vent Damper		*	Electric 20-30% Pneumatic/8/ Thermal	0-5% 5-9% /9/10/ 0-2%	*	*
Flue Restrictor	*	*		20% /11/	*	
Electric Ignition		*		3.5% /11/	*	*
Heat Reclaimer	*		Up to 30% /12/	2-11% /9/	*	

NEW FURNACE DESIGNS

The other trend in efforts to improve gas furnace efficiency has been the redesign of the conventional gas furnace. The pulse combustion furnace is an example of such redesign. With a seasonal efficiency of 95%, it is considered by many in the industry to be the state-of-the-art in gas furnace design. Despite this claim, other types of gas systems have evolved:

1) Conventional with options such as flue dampers and electronic ignition - 60 to 75% seasonal efficiency range

2) Improved or alternate heat exchanger with controlled burner rate - 75 to 85% seasonal efficiency

3) Same as 2) but with an additional stage of heat exchange which condenses flue gas - >85% seasonal efficiency

4) Hybrid or dual fuel systems such as combination heat pump gas furnaces or gas-fired water heater/furnace combinations - various efficiencies.

Table 2 lists the actual furnaces that have been developed under categories 1,2,3 above. A more detailed description of each one can be found in Appendix 1. Some discussion of the 4th category follows the Table.

TABLE 2

HIGH EFFICIENCY FURNACE TYPES

Furnace Type	Category	Efficiency		Reference	R&D Stage		
		Steady-State	Seasonal		Idea	Prototype	Product
Conventional		75-80%	55-65%	1			*
Conventional With Electronic Ignition & Damper Options	1		60-75%	1,16 2			*
High Efficiency Heat Exchanger With IDV* Non-Condensing	2		80%	17,1 18			*
Heat-Pipe Non-Condensing	2	85%	83%	1,7		*	
Gas-Fired Water Filled Heat Exchanger With Steam Powered Blower	3		80+%	1		*	
Conventional With 2nd Stage Condensing Heat Exchanger & IDV*	3	92-98%	92-96%	19, 20,21			*
Pulse Combustion With Condensing Heat Exchanger	3	98%	94-96%	1,2			*
Fluidized Bed With Condensing Heat Exchanger	3	95%		1		*	
Heat-Pipe Condensing	3	90+%		1	*		

* Induced Draft Ventilation

HYBRID AND DUAL FUEL SYSTEMS

At least one hybrid system has been developed in Canada which utilizes heat pump technology and an outdoor gas burner. The Koolfire heating/air conditioning system uses a gas fired burner to heat the outdoor coil when the heating demand in the house is higher than the heat pump capacity. The heat is transferred indoors by the freon filled piping shared with the heat pump system. Tests by both the Canadian Gas Research Institute (CGRI)/13/ and Ontario Hydro/14/ have shown the system to operate in the gas mode at an average 95% efficiency, steady state. Initially the heat pump operated at a low COP, but heat pumping efficiency is being improved in later models.

More systems are available in the U.S. For example the Amana Heat 'n' Hot Water System introduced in 1982 uses an outdoor burner to heat a propylene glycol/water solution in coiled copper pipes. The vapourized solution is pumped indoors where it condenses in either the water tank or the air heat exchanger, depending on where it is needed/15/.

3.0 OIL FURNACE

Oil-fired space heating furnaces were used in the majority of residences in Canada prior to 1960. An ever growing network of natural gas pipelines has allowed more and more homeowners to switch over to natural gas. Still, in many areas of Canada natural gas is not available, and despite the economic advantages of changing to a less expensive fuel, homeowners are continuing to utilize oil fired heating equipment.

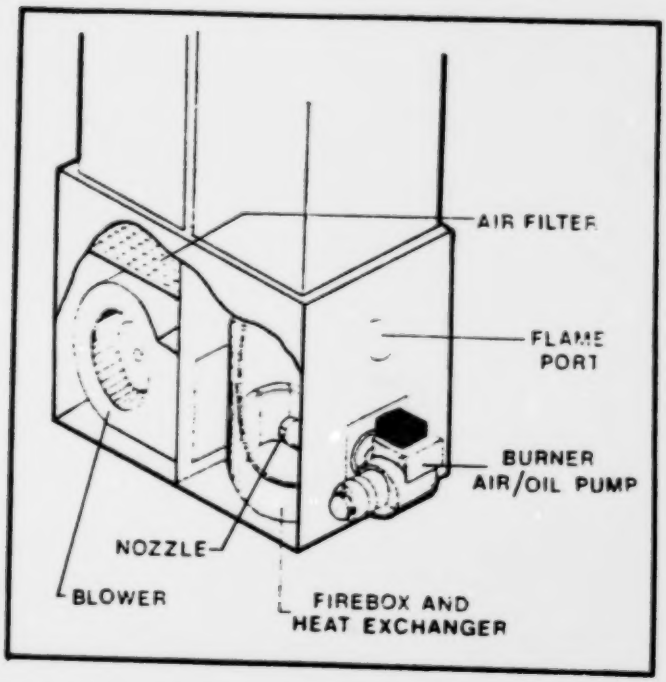
OPERATION

An oil furnace is very similar to a conventional gas furnace in terms of components and operation, with the exception of the burner which requires an oil pump to draw and mix the fuel before firing it into the combustion chamber. As was the case with the gas furnace, the oil furnace operates in an on-off-cycle pattern controlled by a thermostat. Similar losses are associated with each period of the cycle.

Referring to Figure 2, when the thermostat demands heat, the burner is energized. It pumps oil and air into the nozzle where the oil is atomized, mixed with air and ignited by an electric spark. The resulting flame is directed into the fire box, where the heat of combustion warms up the entire heat exchanger. As the ambient air around the heat exchanger is warmed, a thermally actuated switch brings on the blower, and heat is transferred to the warm air delivery system/4/.

FIGURE 2

CONVENTIONAL OIL FURNACE



OIL FURNACE INEFFICIENCY

Heat losses occurring in an oil fired furnace are very similar to those experienced by a natural gas furnace. There are on-cycle losses, off-cycle losses and total losses.

ON-CYCLE LOSSES

The on-cycle losses result in a combustion efficiency which is in the range of 50 to 85%/22/. This wide range of efficiency illustrates the extent to which combustion efficiency can vary, depending on such factors as burner and heat exchanger design, burner calibration, and degree of maintenance for the system. Stack losses of up to 25% combustion air losses of 2%, latent heat in water vapour 6%, and other losses all contribute to this efficiency range/6/.

OFF-CYCLE LOSSES

Off-cycle losses in an oil furnace are generally lower than for a gas furnace for several reasons. First, there is no standing pilot to encourage off-cycle stack loss, and second, dilution

air for flue gas is controlled by a damper, which remains closed for most of the off-cycle. Off-cycle duration has a much greater effect on oil furnace efficiency than gas, because the typical oil fired combustion chamber and heat exchanger is made of cast iron, and has a much higher thermal mass than the typical gas heat exchanger. This means that oil furnaces require a relatively long time to heat up, and ideal conditions would favour a short off-cycle. As oil furnaces are generally oversized, this is not usually the case, and much energy is wasted by the stored heat in the case iron heat exchanger, which slowly cools down during the off-cycle, dissipating the stored heat up the chimney.

As a result of the cyclic losses discussed, the seasonal efficiency of the typical oil furnace falls within the range 46 to 76%/22/. From the documentation available it appears that efforts to improve this efficiency have, up to the time of this report, been concentrated on retrofit devices as opposed to new furnace designs. This is due mainly to the fact that oil furnace manufacturers do not appear to be concerned about improving their product, as they can sell gas appliances just as well. This has left the onus on the oil companies to improve efficiency on existing installations in an attempt to maintain their market. For the most part, high efficiency oil furnaces are the same old design with a new burner and one or two other options.

Another reason that appliance manufacturers have not expended much effort in developing radically improved oil burning equipment is that the Federal government is supporting off-oil programs. The termination of the COSP program in Canada is expected to encourage far more effort in improving oil furnace efficiency than has been seen for awhile.

Alternate methods exist that reduce the cost of operating an oil furnace. Electric plenum heaters, heat pumps, and add-on wood-burners are the major options. Although these systems reduce energy costs, they do not affect oil furnace performance, and hence fall outside the scope of this report.

RETROFIT DEVICES FOR INCREASED EFFICIENCY IN OIL FURNACES

The list of retrofit devices for oil-fired furnaces includes many of those available for gas furnaces, such as dampers, add-on flue mounted heat reclaimers, and flue restrictors. One item exclusive to the oil furnace is the high efficiency oil burner. This device has been redesigned by several manufacturers and is heavily marketed as a cost saver by the oil companies. Features of the new burners are better oil/air mixing, pre-heating of the fuel and improved ignition.

It should be noted that unlike the gas furnace situation, oil furnace devices which affect flue temperature and flow are approved for retrofit in many parts of Canada. There are several reasons for this. First, the conventional oil furnace requires much less dilution air in the exhaust than the conventional gas furnace, and it is controlled by a barometric damper. This results in oil flue products being exhausted at a much higher temperature than gas flue products. Second, the moisture content of oil flue products is half of that found in gas flue products, reducing the danger of condensation in the chimney. A non technical reason which is probably weightier involves jurisdiction; oil furnaces and equipment are approved by Canadian Standards Association (CSA), while gas-fired appliances are subject to the approval of the Canadian Gas Association (CGA).

A survey of the available devices for retrofit has been summarized in Table 3.

TABLE 3

RETROFIT DEVICES AND EFFICIENCIES OIL FURNACES

Device	Cycle		Efficiency		Installation	
	On	Oft	Claimed	Tested	Retrofit	New
Damper		*		6% /23/	*	
Heat Reclaimer	*		95% /24/		*	
New Burner	*		86% /25/	17% /26/	*	*

4.0 GAS WATER HEATERS

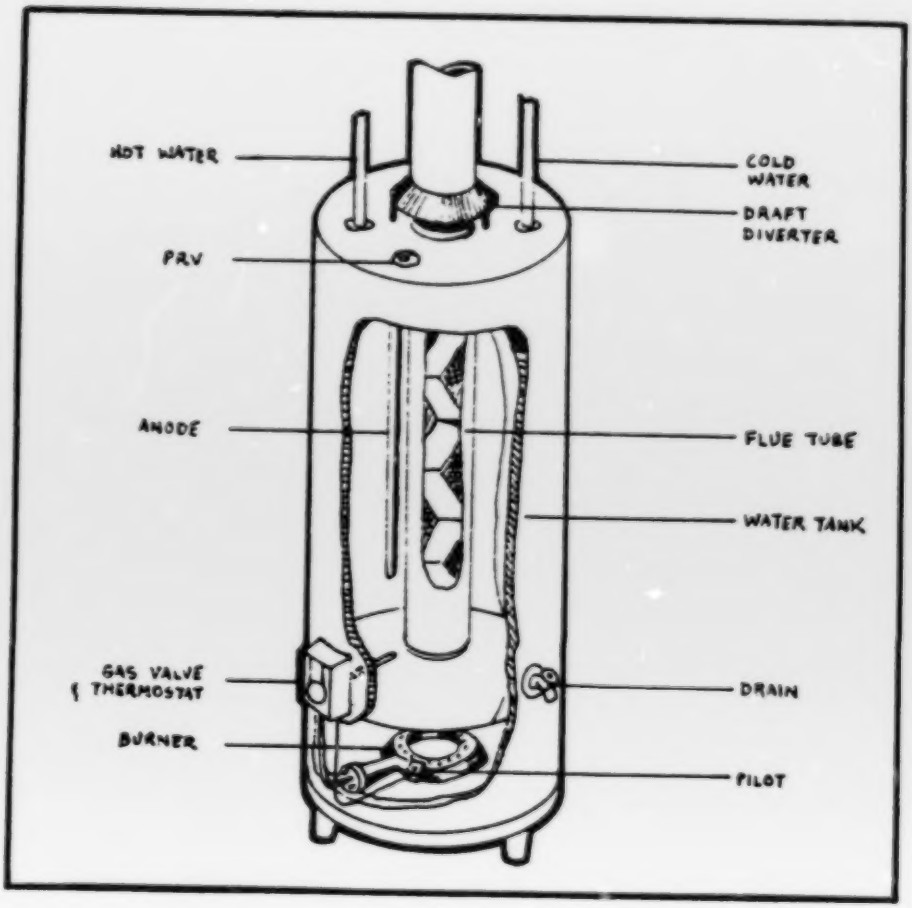
The conventional gas-fired water heater has been used extensively since the 1940's. Its growth in popularity has increased with the expanding availability of natural gas. The conventional water heater usually installed in residences is about 50 to 60% efficient seasonally/3/, current gas prices making it roughly as expensive to operate as a conventional electric water heater/31,32/. In recent years however, much research has been undertaken to improve water heater efficiency, as part of the general trend toward energy conservation, and

production appliances are now available which are less expensive to operate than their electric counterparts. Again, the best way to understand the improvements is to briefly examine the operation and losses of the conventional appliance, and compare it to the high efficiency types.

Figure 3 illustrates the components of a conventional water heater. When the thermostat senses water temperature below the setpoint it engages the single port burner which fires up. The water is heated in two ways; the radiant heat in the flame heats the tank bottom, which conducts it to the water, and the convective current of flue gas up the central flue pipe passes more heat to the water before leaving the tank.

FIGURE 3

CONVENTIONAL GAS WATER HEATER



Again efficiency is defined two ways. The steady state or recovery efficiency is the percent of heat released by combustion that actually heats the water while the burner is on. For conventional water heaters this value is in the range 70 - 75%/3/. The remaining 25-30% is heat lost up the flue, and 1 or 2% is lost by conduction through the jacket and pipe connections. The real seasonal or utilization efficiency is much lower due to the off-cycle losses incurred when the burner is off. These include a 13-19% stack loss, and a 4-7% standby loss as heat escapes down the pipes and legs connected to the heater/3/.

In gas water heaters, efficiency has been improved by reducing or eliminating these losses both with retrofit devices and new heater designs. Unlike electric water heaters, increased insulation does not significantly reduce off-cycle losses, because the major portion of heat is lost due to stack effect. For this reason, flue dampers have had a favourable review as an efficiency boosting device. Several new designs for gas water heaters have concentrated on removing the flue from the tank. Another alternative is to eliminate the storage tank altogether as in the case of the instantaneous water heater. These devices are summarized below in Table 4 and explanations appear in the notes following.

TABLE 4

GAS WATER HEATER EFFICIENCY

Type	Efficiency	
	Recovery	Seasonal
Conventional	70-75%	50-60%
With Flue Damper	Note 1	50-70%
Submerged Burner Chamber	85% Note 2	
AMTI High Efficiency Water Heater	82% Note 3	
Instantaneous Gas Water Heater	80% Note 4	80%

NOTES

1) Flue Damper Efficiency - According to various sources, flue dampers can add from 0 to 10% to the seasonal efficiency of a gas water heater. Most conventional water heaters have a pilot type burner which means the damper must be slightly open to allow flue gas to escape during off-cycles. This in turn causes the stack effect to remain high, as stack flow is not proportional to flue restriction size. Essentially, if the damper cannot block the flue completely, it will have minimal effect on stack loss/27/.

2) Submerged Burner Chamber - Marketed in the United States by Moreflo Industries, this water heater features a combustion chamber inside the water tank, as opposed to underneath, as in the conventional style. With this design, heat that normally escapes to the air out the sides and bottom of the appliance instead is transferred to the water. Recovery efficiency is improved, but standby losses are not reduced/28/.

3) AMTI High Efficiency Water Heater - A radical change from the conventional water heater, this design removes the burner and flue from the tank. The burner heats water in a finned tube heat exchanger which is connected by pipes to the tank. Natural convection keeps the water flowing through the pipes between the tank and the burner. The tank is a one piece moulded polyethelene container, surrounded by foam insulation and encapsulated in a steel pressure vessel, which supports and protects it. The high recovery efficiency and good storage characteristics are its strong points. Seasonal efficiency is predicted to be in the 70 to 75% range however, which causes some suspicion about the off-cycle losses/29/.

4) Instantaneous Water Heaters - The greatest losses associated with water heater operation occur because of the storage factor necessary to provide a constant supply over a range of load conditions. An alternative to the storage tank is the instantaneous water heater, which switches on a high capacity heat source to bring water up to setpoint temperature as it passes through the appliance. Electric types have been available from Europe for a long time but have not been popular here because of the heavy wiring required and the peak loading they would represent. While peak loading is not a significant problem for gas utilities, the lack of good variable rate gas burner to provide a constant output for different demands has till now inhibited the availability of such a device. At least one Japanese manufacturer has created a microprocessor controlled burner for an instantaneous water heater which is expected to be marketed here in the near future/30/.

5.0 ONTARIO HYDRO AND GAS WATER HEATERS

Ontario Hydro's experience with gas water heaters is limited to some testing sponsored by the Residential Marketing Department and conducted by the Research Division. The results have been published in two reports both of which are listed in the reference section of this report/31,32/.

In the first report, side by side thermal performance tests were conducted for one electric and two natural gas water heaters. All three heaters were subjected to a variety of daily water draw schedules as specified in the relevant CSA and Standards Council of Canada (SCC) standards. From the data collected, it was determined that the operating costs for both types of water heater are roughly equal. For high water draws the gas heater was slightly cheaper to operate, while electric heaters operated more economically at low water draws. It was confirmed that the gas water heaters had a utilization efficiency of between 50 and 60%. It was also noted that recovery time for a gas water heater is about half that required for an electric heater.

In the second report, further tests were conducted to determine the crossover point in water draw at which electric heaters became more economical to operate than gas water heaters. The effects of the relatively slow recovery time for electric heaters under high demand conditions was studied. It was concluded that recovery rates for both electric and gas heaters are fast enough to permit sufficient hot water supply for high demand conditions. In fact, the higher output gas burner can create conditions of temperature overshoot during heavy draw patterns, which may pose a safety problem.

For complete details on these tests, refer to the reports listed in the reference list. It is expected that future research will be undertaken to determine the effects of various retrofit devices on the thermal performance of gas water heaters, and how this will compare with electric heater performance.

6.0 CONCLUSIONS

With regard to efficiency, the state-of-the-art for the three appliance areas studied varies considerably:

1) Gas furnaces are now available across a wide range of efficiencies proportional to the amount of money the consumer is willing to pay. They are available with seasonal efficiencies of 60 to 95%.

2) Although high efficiency oil furnaces have not yet evolved, there are indicators that they will present a challenge in the future. At present, add-on devices such as heat reclaimers are claimed to increase efficiency to the 90% range.

3) Improvements in natural gas water heaters have only recently been studied, but as their present operating costs match electrics, and their market continues to expand, economic incentives would appear to inhibit serious work in this field.

7.0 RECOMMENDATIONS

1. More experience needs to be gained in the area of natural gas, particularly with regard to water heaters, in order to understand efficiencies and potential improvements in this field.

2. Some contacts were made with organizations involved in gas and oil research which proved to be very informative and helpful with regard to efficiency and energy conservation. These contacts should be maintained and dialogue encouraged, in order to keep abreast of the developments in these areas.

3. To gain more understanding of residential heating with natural gas, it would be useful to obtain appropriate National Standards governing its use. These standards are written by the Canadian Gas Association and are approved and listed by the Standards Council of Canada.

4. During the research portion of this project, it was felt by the author that Hydro information resources were scarce in the areas of furnace research and development. In order to

keep abreast of current events, it is recommended that Hydro subscribe to and circulate periodicals dealing with the residential heating industry.

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APPENDIX 1

DESCRIPTION FROM TABLES 1 & 2

Automatic Vent Dampers (AVDs)

AVDs are dampers installed in the flue pipe and close off the flue when the furnace is not running, thereby reducing the off-cycle stack losses up the chimney. There are three types of damper actuators:

Electrical - when the furnace switches off this type energizes a motor to shut the damper while winding up a spring. If electric supply is lost, the spring will unwind causing the damper to fall open. This type is available as a retrofit or factory installed option.

Pneumatic - gas pressure is utilized to open the damper when the furnace gas valve is energized.

Thermal - the damper blades are made of a bimetal which causes them to warp open when heat from the flue gas is sensed. This type has been in use in Europe for over 40 years.

The effectiveness of an AVD will depend on the amount of off-cycle stack loss for a given furnace installation. Such factors as flue diameter, off-cycle duration and wind conditions can create potential for efficiency improvements of 0 to 25%.

Flue Restrictor

A flue restrictor is a reduced diameter flue section that can be inserted in the flue. By restricting the flow of flue gas out of the heat exchanger, more heat can be transferred to the heated space. Flue restriction can cause the heat exchanger to wear out prematurely because it is forced to operate at higher temperatures.

Electronic Ignition

Standing pilot losses can be eliminated by installing an electronic ignition gas valve assembly. For retrofit applications a spark type ignitor is used to light the existing pilot whenever there is a demand for heat. In new furnaces equipped at the factory with electronic ignition, a glow type ignitor is used. Every manufacturer of burner controls in North America now offers a line of electronic ignition systems, which gives an indication of their extensive use.

Heat Reclaimers

Heat reclaimers are actually second stage heat exchangers which mount in the flue and capture some of the heat remaining in the flue gas. The efficiency of a heat reclaimer is proportional to its price because increased efficiency requires increased complexity. Units which condense the flue vapour must have a non-corrosive heat exchanger, as well as a blower to exhaust the cooled flue gas. A wide variety of devices are available, most of them being designed and manufactured in the U.S.

IMPROVED FURNACE DESIGNS REFERENCED IN TABLE 2

Conventional Furnace With Options

Many manufacturers are offering a high efficiency conventional gas furnace which includes the options of electronic ignition and an automatic vent damper. As the table indicates, these furnaces are about 10% higher in efficiency than conventional models. They are generally approved for sale in Canada because the responsibility for safe operation of the controls rests with the manufacturer instead of the installer.

Improved Efficiency Heat Exchanger With Power Vent Non Condensing

This furnace type is similar in design to the conventional furnace except for two modifications. First the heat exchanger has been improved to transfer greater than 80% of the heat of combustion and second, a small blower is installed in the flue to guarantee proper venting of the cooler flue gasses. When the flue blower is not running, stack losses are greatly reduced resulting in the efficiencies claimed by the manufacturer.

Heat Pipe Furnace Non-condensing

In this furnace, the conventional clamshell heat exchanger is replaced by a set of sealed, water-filled pipes. One end of each pipe protrudes into the burner chamber, where the flame vapourizes the water so that it rises to the other end of the pipe located in the warm air chamber. As heat is transferred to the air the water condenses and falls back down to the burner end. The heat transfer characteristics of water are such that the size of the heat exchanger is half that of a conventional furnace. A furtner advantage is that the heat exchanger efficiency is constant over a wide range of burner firing rates. This means that the furnace output can be throttled or modulated proportionally to the heat demand, thereby eliminating the on-off-cycle operation of the conventional furnace, and the resultant losses. While heat pipe furnaces show a lot of

promise, they are not expected to be a commercial success, as there are less expensive furnaces available with higher efficiencies.

Gas-fired Condensing with Steam-powered Blower

A furnace developed by Thermal Research Corporation in 1980 uses a small gas-fired boiler to generate steam. The steam drives a turbine which is connected to the furnace blower. A heat exchanger is connected to the turbine outlet and condenses the steam, passing the heat to the warm air ductwork. According to the developer, when the energy saved by using steam power instead of electricity to drive the blower is credited to the system, the efficiency is 80%. Again, the success of the prototype does not indicate a large commercial potential, as there are more efficient less expensive furnaces available.

Improved Efficiency Heat Exchanger With Power Vent Condensing

This furnace is similar to the improved conventional furnace described above with the addition of one extra stage of heat exchange. This last stage is a condensing heat exchanger which recovers the latent heat found in the water vapour portion of the flue gas. The Clare Megasave is the first of many brands now being marketed which incorporate all these features. Next to the pulse combustion furnace, this type is the most highly efficient furnace on the market today.

Pulse Combustion Furnace

Another furnace possessing steady state efficiency in the mid-90's, the pulse combustion furnace was developed by American Gas Association and produced and marketed by Lennox Industries. This furnace uses a combustion chamber heat exchanger and tailpipe for primary heat exchange. The shock wave produced by each pulse of combustion controls the gas/air valves and provides enough pressure to drive the flue gas through a condensing heat exchanger and out the flue. Thus the need for a power vent is eliminated. While pulse combustion furnaces are highly efficient, they suffer from vibration and require careful installation involving the use of noise suppressors at the duct connections.

Fluidized Bed With Condensing Heat Exchanger

Except for the heat pipe furnace, all the furnace types discussed so far effect heat exchange by convection from air to air through the steel heat exchanger walls. Higher rates of heat transfer can be effected by passing air through a fluidized medium, such as sand. This method of heat transfer is being

examined in a high efficiency furnace developed by IGT. In the prototype, a coarse-finned heat exchanger is buried in a bed of material, which becomes fluidized as air is forced through it. Heat transfer occurs at a much greater rate than had the air simply passed across the heat exchanger surface. The prototype also has a second stage condensing heat exchanger which extracts the remaining exhaust heat. This furnace is designed for small heating loads in the 25,000 BTU category.

Heat Pipe Condensing

Identical to the heat pipe furnace mentioned previously, this furnace as an additional stage condensing heat exchanger which captures the majority of the flue gas heat, bringing its efficiency up to the >90% range.